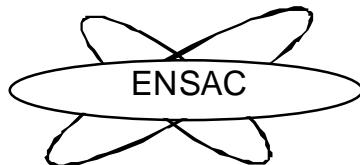




ENTE PER LE NUOVE TECNOLOGIE, L'ENERGIA E L'AMBIENTE  
Associazione ENEA-EURATOM sulla Fusione  
FUSION UNIT  
TECHNOLOGIES DIVISION



ENSAC ASSOCIATES Ltd.

## Tokamak ORE data collection

Princeton, October 2003

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## **TASK OBJECTIVE**

Collect and evaluate available tokamak ORE data (individual doses and collective doses) in normal and abnormal operation

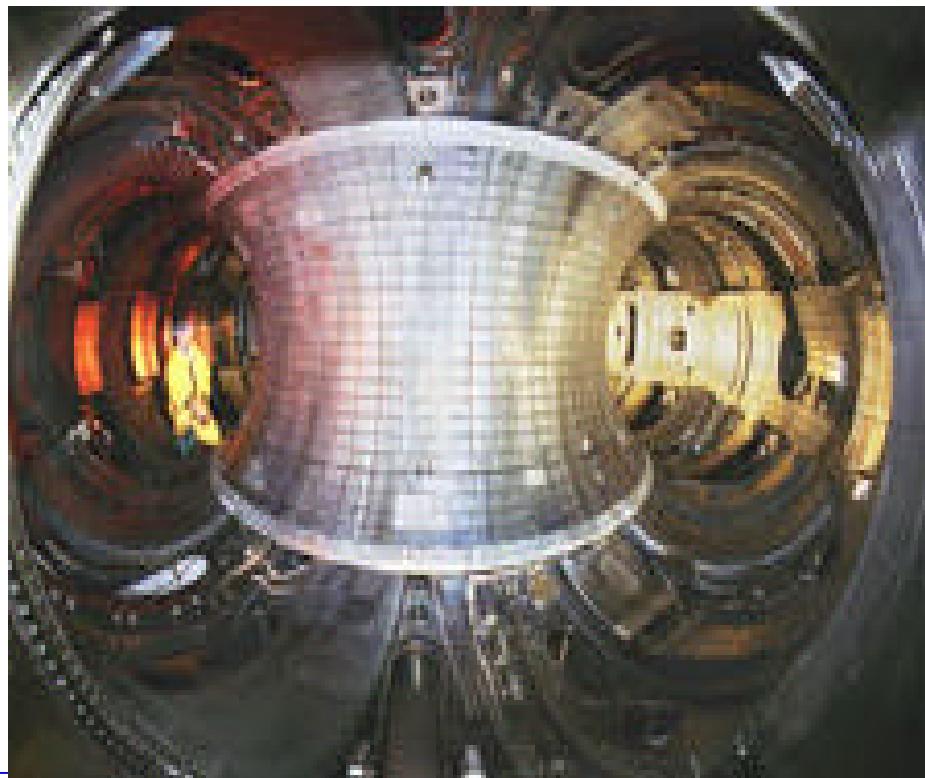
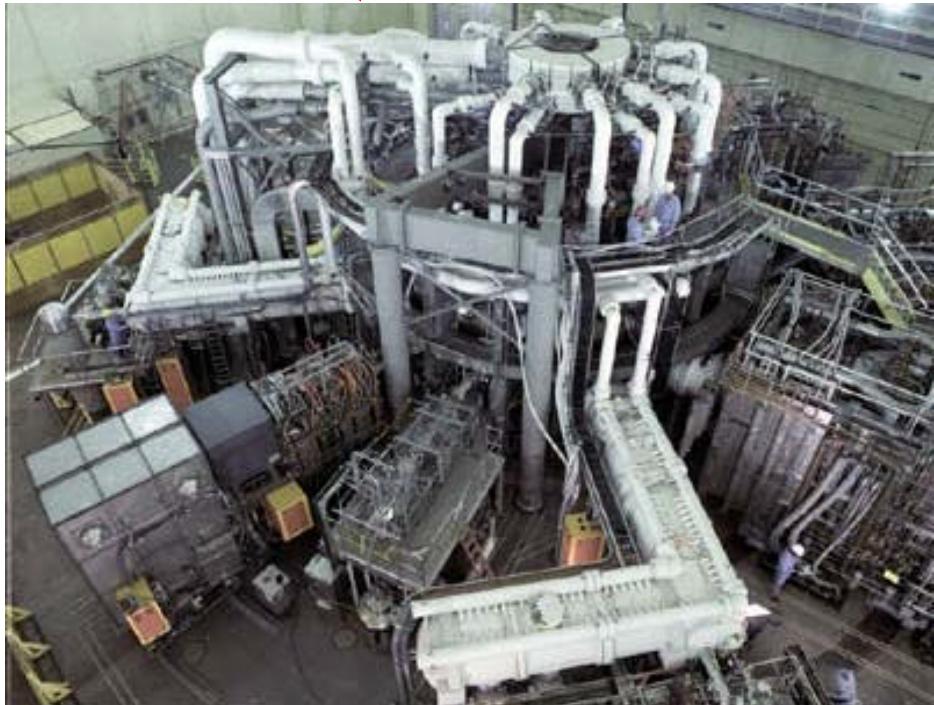
**data available from:**

- **TFTR**
- **JET**
- **DIII-D (?)**

## TFTR (Tokamak Fusion Test Reactor)

- TFTR operated at the Princeton Plasma Physics Laboratory between 1982 and 1997.
- In December 1993, tritium was used for the first time in a fuel mix of 50% deuterium and 50% tritium.
- The initial tritium experiments yielded 6.0 MW of fusion power. By November, 1994, tritium shots achieved 10.7 MW for a few seconds.
- Of the approximately 60,000 high-power plasma pulses produced in TFTR, more than 1,000 contained a deuterium-tritium fuel mixture.

# TFTR (Tokamak Fusion Test Reactor)



# TFTR (Tokamak Fusion Test Reactor)

TFTR was shut down in 1997, following 15 years of operation.  
Dismantling began in 1999, after two years of cool-down

Activity	Date
Project Start	October 1999
Remove Umbrella Structure	November 2000
Complete Removal of Vacuum Piping	July 2002
Tokamak Removal Complete	July 2002
Removal Complete	September 2002

# TFTR (Tokamak Fusion Test Reactor)

## Removal of Umbrella Structure



## TFTR Operation

- TFTR generally operated for 3 or 4 consecutive weeks
- followed by a week of routine maintenance
- The period of plasma operation generally lasted about 20 weeks/year
- Following this period, major upgrades and maintenance activities would be performed
- A typical run day during the D-T phase consisted of two eight-hour shifts of operation with about 60-80 plasma discharges per day
- Each discharge lasted 1 sec or less

# TFTR - Annual Worker Dose Summary

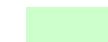
Year	Total Number Monitored'	Number with Meas. Dose	Total Collective Dose		Average Meas. Dose	
			p-mSv	p-mRem	mSv	mRem
1987	1089	185		?		?
1988	1116	160		?		?
1989	881	218	77.1	7710	0.354	35.4
1990	604	184	63.1	6310	0.343	34.3
1991	593	153	56.1	5610	0.367	36.7
1992	852	126	41.5	4150	0.329	32.9
1993	836	92	29.6	2958	0.322	32.2
1994	473	101	31.6	3155	0.312	31.2
1995	297	70	32.5	3254	0.465	46.5
1996	313	104	60.2	6023	0.579	57.9
1997	303	102	37.5	3752	0.368	36.8
1998	176	35	10.8	1080	0.309	30.9
1999	224	34	8.2	817	0.240	24.0
2000	322	59	29.4	2941	0.498	49.8
2001	374	108	74.2	7420	0.687	68.7
2002	426	145	37.1	3707	0.256	25.6
<b>AVE.</b>	<b>555</b>	<b>117</b>	<b>42.1</b>	<b>4206</b>	<b>0.359</b>	<b>35.9</b>



Tritium Operations

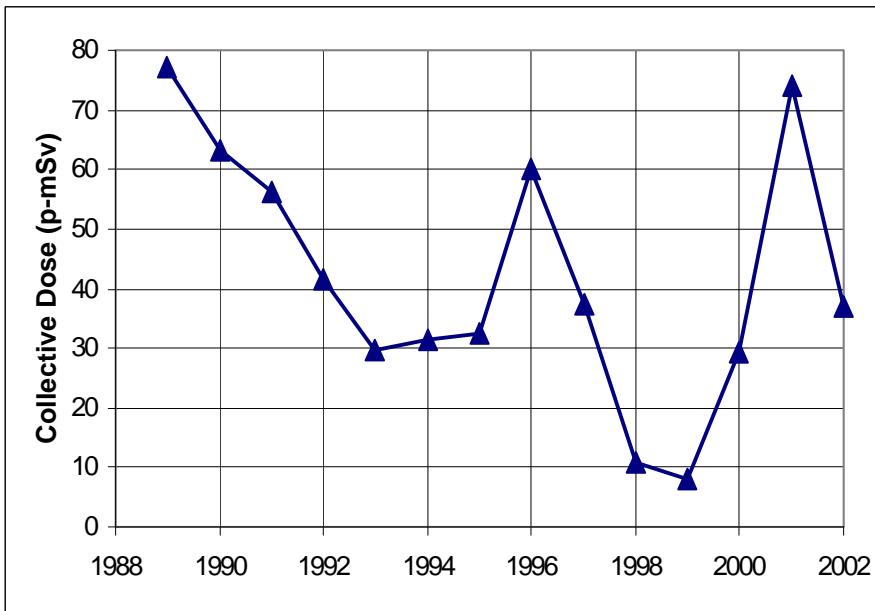
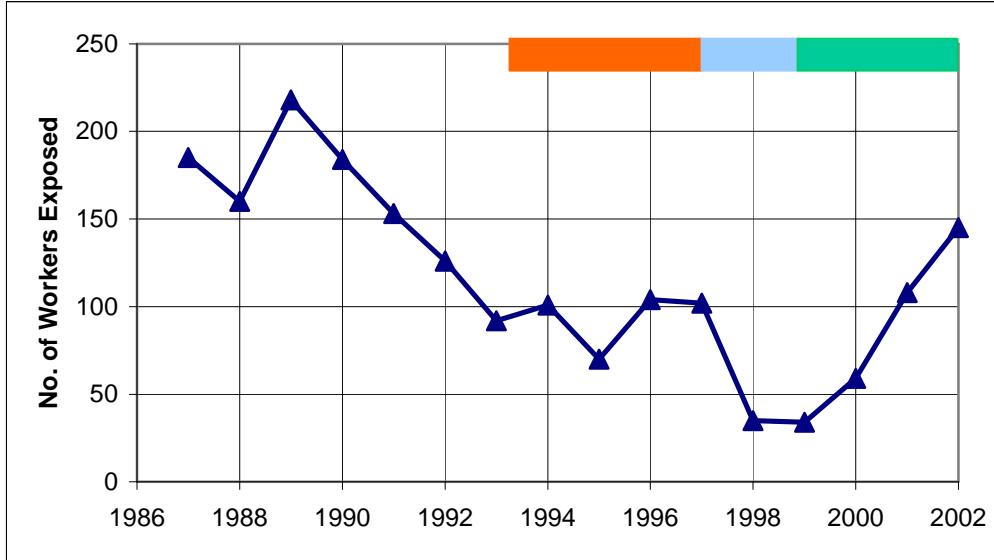


Dormancy period

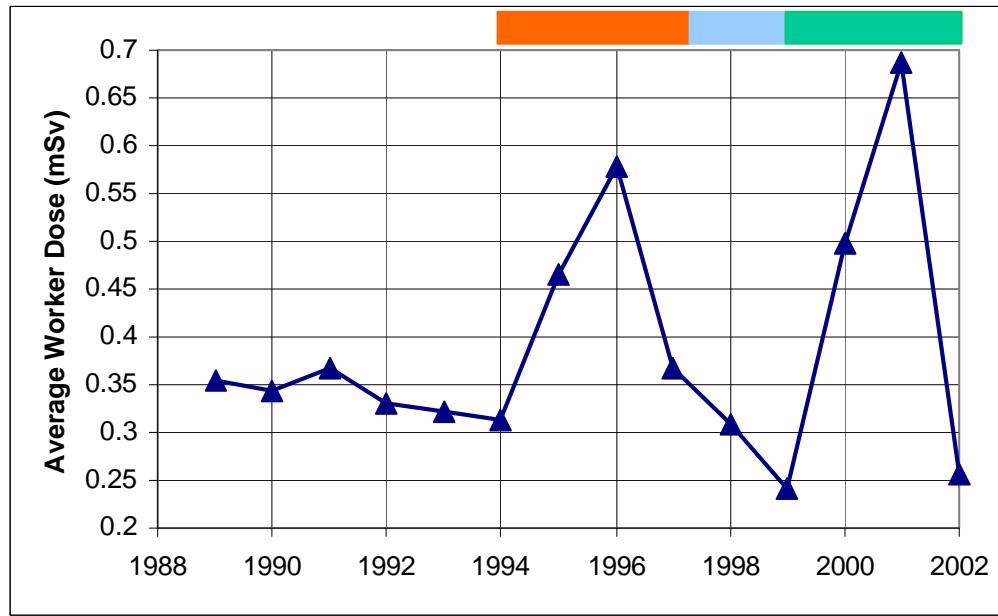


Dismantling

# TFTR - Annual Worker Dose Summary



# TFTR - Annual Worker Dose Summary



# TFTR - Annual Worker Dose Summary

## Collective Dose by Worker Category (p-mSv)

<b>Worker Category</b>	<b>1989</b>	<b>1990</b>	<b>1991</b>	<b>1992</b>	<b>1993</b>	<b>1994</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>AVE</b>
Administrative support	3.5	2.3	0.7	0.8	0.3			0.6	1.1	1.3
Engineering support	16.5	14.4	10.9	8.6	3.4	4.2	6.0	4.5	5.0	8.2
Operations	1.0	1.4	2.3	0.9	2.0	3.8	3.9	9.1	4.4	3.2
Other	10.8	7.5	2.3	2.8	2.7	1.6	0.0	0.4	0.4	3.2
Safety/health physics	0.9	1.9	1.5	1.8	2.3	1.3	1.8	6.3	1.5	2.2
Scientific support	3.7	2.8	1.4	3.7	3.9	0.3	0.7	3.1	3.0	2.5
Tradesmen	21.2	19.2	16.7	11.7	7.4	9.5	9.4	15.9	5.4	12.9
Technical support	19.5	13.6	20.3	11.2	7.6	10.9	10.7	20.3	8.6	13.6
<b>TOTALS</b>	<b>77.1</b>	<b>63.1</b>	<b>56.1</b>	<b>41.5</b>	<b>29.6</b>	<b>31.6</b>	<b>32.5</b>	<b>60.2</b>	<b>29.4</b>	<b>46.8</b>

# TFTR - Annual Worker Dose Summary

Collective Dose by Worker Category (p-mSv)  
Dormancy & Decommissioning Period

<b>Worker Category</b>	<b>1998</b>	<b>1999</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>AVE</b>
Administrative support	0.2		0.2	0.6	0.1	0.3
Engineering support	2.3	1.3	1.7	4.0	3.9	2.7
Operations	2.7	3.2	3.0	2.2	0.9	2.4
Other		0.4	0.6	3.7	2.2	1.7
Safety/health physics	1.2	0.9	1.3	5.5	3.6	2.5
Scientific support	1.2	0.3	0.6	0.2	0.3	0.5
Tradesmen	1.7	0.6	2.2	6.2	5.1	3.2
Technical support	1.6	1.5	19.8	51.8	20.9	19.1
<b>TOTALS</b>	<b>10.8</b>	<b>8.2</b>	<b>29.4</b>	<b>74.2</b>	<b>37.1</b>	<b>31.9</b>

# TFTR - Annual Worker Dose Summary

## Individual Dose by Worker Category (mSv)

Worker Category	1989	1990	1991	1992	1993	1994	1995	1996	1997	AVE
Administrative support	0.32	0.23	0.12	0.16	0.30			0.16	0.37	0.19
Engineering support	0.41	0.35	0.36	0.33	0.26	0.19	0.46	0.20	0.28	0.29
Operations	0.50	0.70	0.58	0.90	0.18	0.27	0.32	0.50	0.34	0.41
Other	0.30	0.28	0.19	0.19	0.27	0.19	0.01	0.14	0.14	0.20
Safety/health physics	0.30	0.32	0.30	0.30	0.21	0.12	0.23	0.70	0.30	0.35
Scientific support	0.22	0.31	0.18	0.25	0.39	0.15	0.23	0.44	0.33	0.30
Tradesmen	0.37	0.39	0.42	0.38	0.43	0.45	0.67	0.93	0.34	0.42
Technical support	0.38	0.34	0.42	0.41	0.40	0.47	0.63	0.88	0.41	0.41
<b>Facility Averages</b>	<b>0.35</b>	<b>0.34</b>	<b>0.37</b>	<b>0.33</b>	<b>0.32</b>	<b>0.31</b>	<b>0.46</b>	<b>0.58</b>	<b>0.33</b>	<b>0.35</b>

well below the ITER target of 2 mSv



# TFTR - Annual Worker Dose Summary

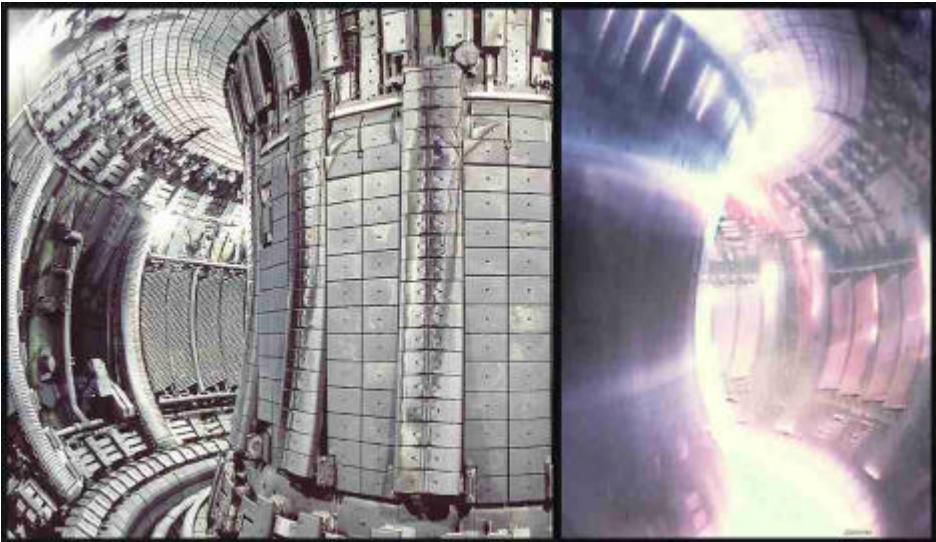
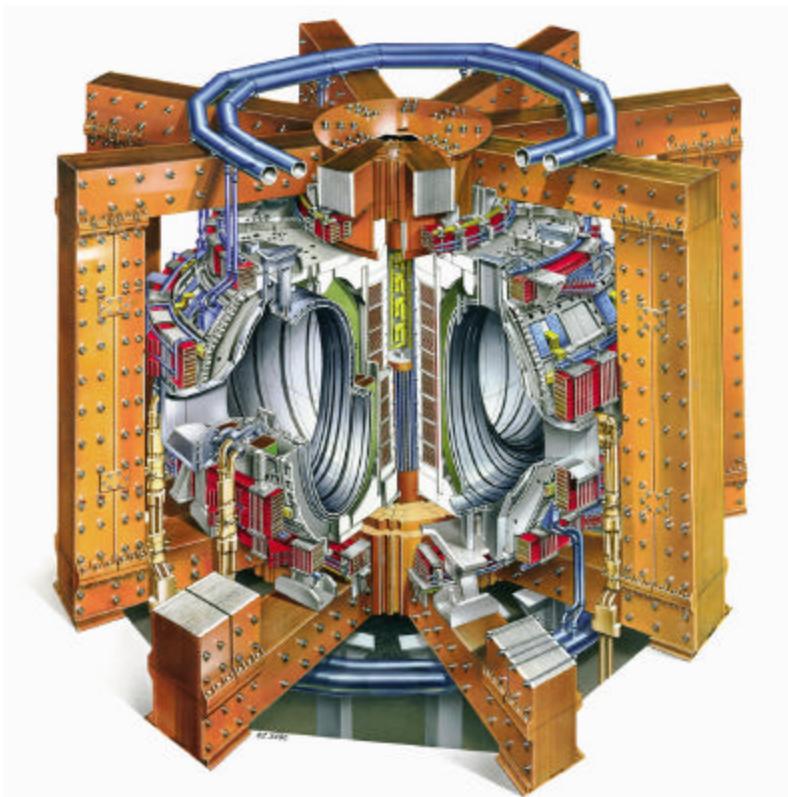
Individual Dose by Worker Category (mSv)  
Dormancy & Decommissioning Period

<b>Worker Category</b>	<b>1998</b>	<b>1999</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>AVE</b>
Administrative support	0.20		0.10	0.30	0.02	0.09
Engineering support	0.26	0.17	0.21	0.20	0.14	0.17
Operations	0.67	0.79	1.00	0.72	0.13	0.41
Other		0.13	0.60	0.47	0.19	0.28
Safety/health physics	0.61	0.22	0.19	0.32	0.30	0.36
Scientific support	0.40	0.15	0.15	0.06	0.03	0.10
Tradesmen	0.24	0.15	0.31	0.44	0.28	0.24
Technical support	0.17	0.17	0.73	1.29	0.40	0.82
<b>Facility Averages</b>	<b>0.31</b>	<b>0.24</b>	<b>0.50</b>	<b>0.69</b>	<b>0.26</b>	<b>0.42</b>

# JET (Joint European Torus)

- The JET Joint Undertaking was established in June 1978
- JET started operating in 1983
- Deuterium-Tritium experiment in 1991 (PTE)
- During 1997 the JET operations included a three-months campaign of Deuterium-Tritium fuel mixtures
- The JET Joint Undertaking, the organization that built JET and operated it for more than 16 years, ceased to be on December 31, 1999

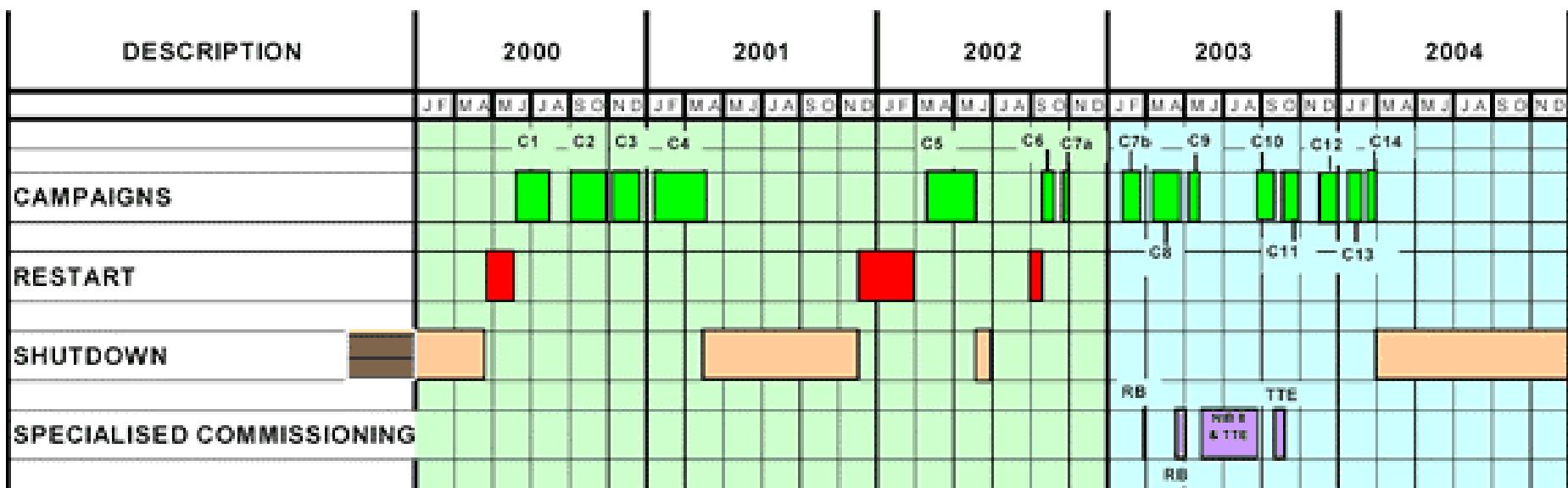
# JET (Joint European Torus)



# JET (Joint European Torus)

Plasma major radius	2.96 m
Plasma minor radius	2.10 m (vertical) 1.25 m (horizontal)
Toroidal Field Coil Power	380 MW
Toroidal magnetic field (on plasma axis)	3.45 T
Plasma current	3.2 MA (Circular plasma) 4.8 MA (D-Shape plasma)
Additional heating power	25 MW

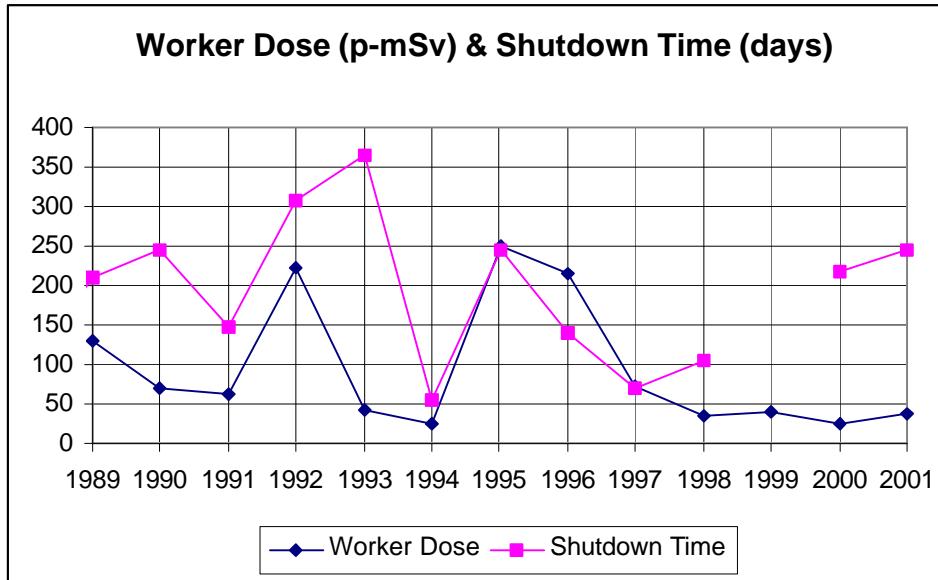
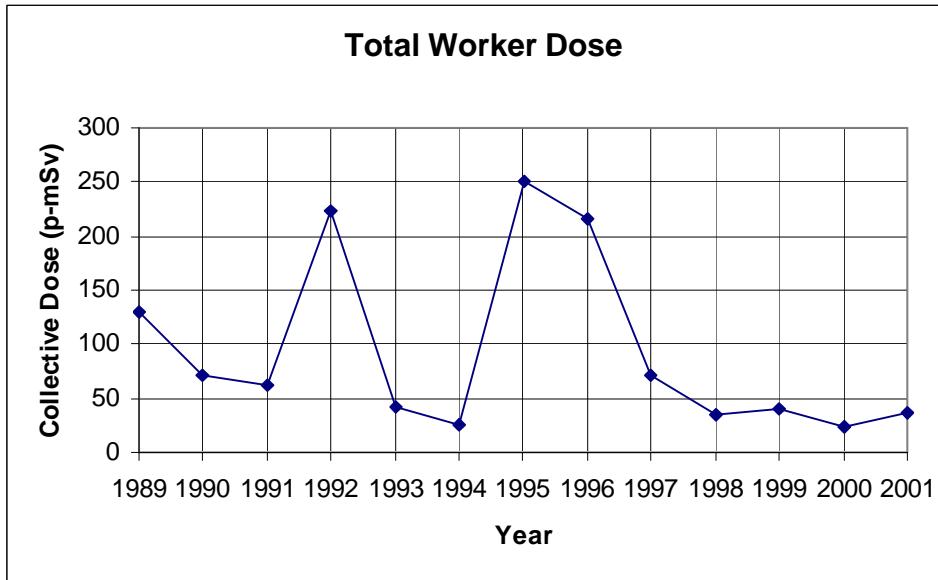
# JET Operation



# JET Annual Maintenance

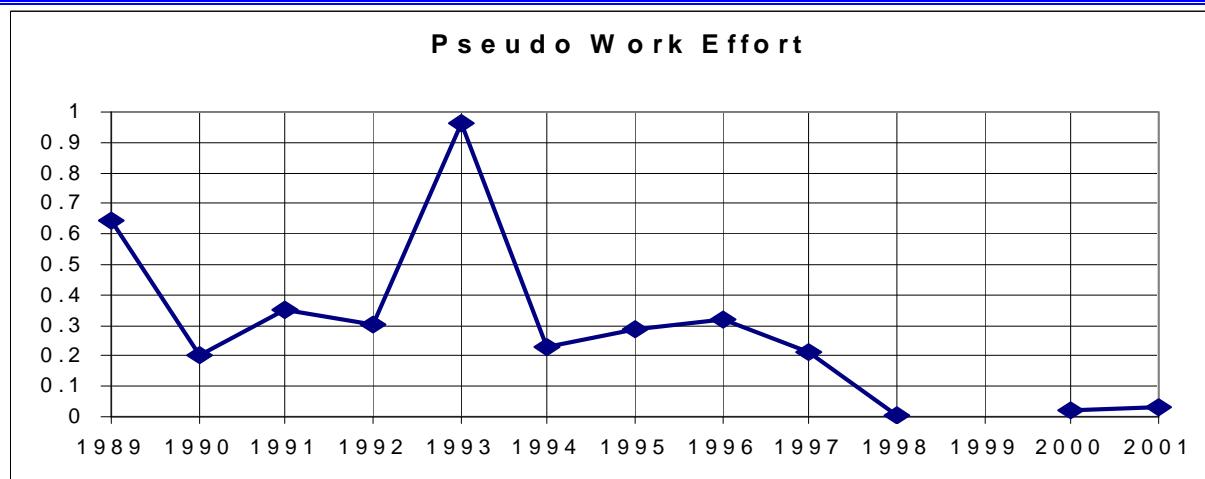
Year	Major Shutdowns		Machine Interventions		
1988	oct - dec				
1989	jan - apr	oct - dec			
1990	jan - jun	nov - dec			
1991	jan - apr		sep		
1992	feb - dec				
1993	jan - dec				
1994	jan		mar	sep	nov
1995	jun - dec		feb	mar/apr	
1996	jan - mar		oct	dec	
1997			feb	apr	jun - jul
1998	feb - mar				
1999					
2000	jan - may		jul - aug	nov	dec
2001	apr - nov				

# JET Annual Worker Dose



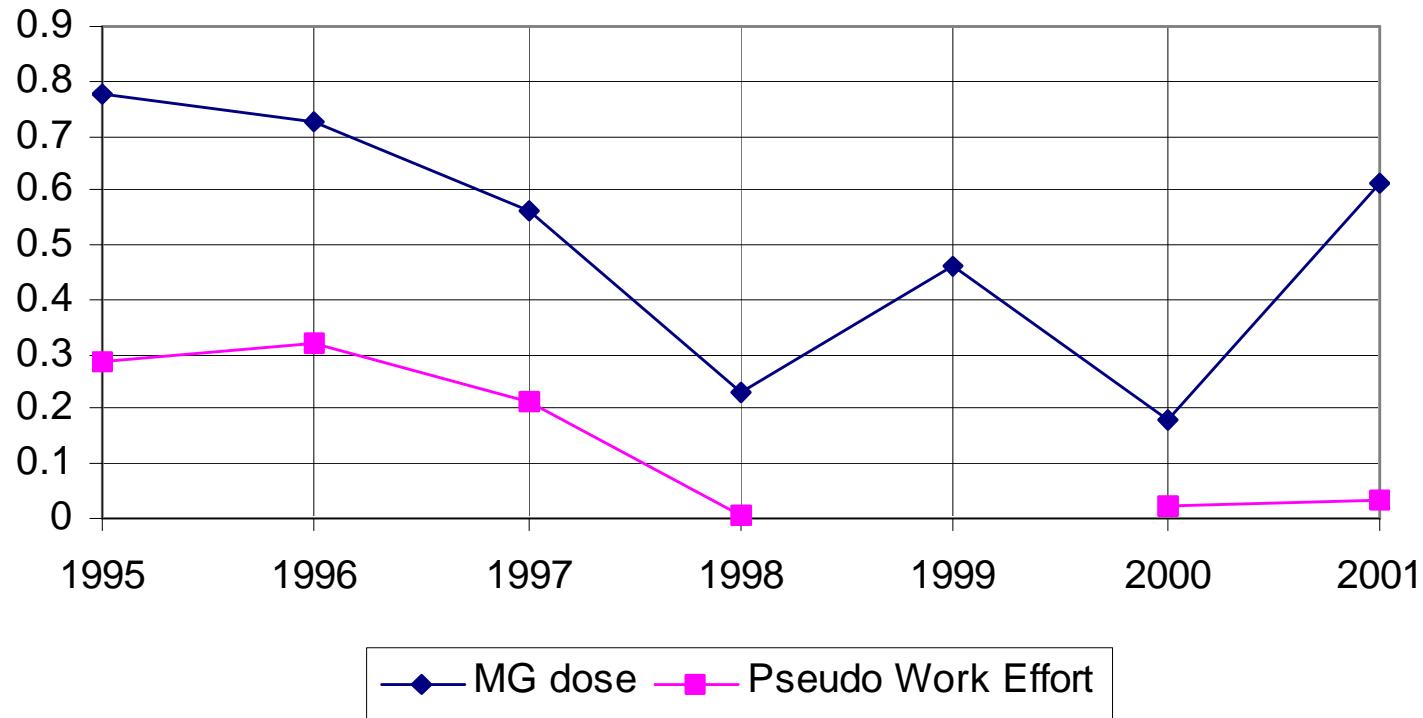
# JET Annual Worker Dose

Year	Worker Dose Rate ( $\text{p-}\mu\text{Sv/h}$ )	Machine Dose Rate ( $\mu\text{Sv/h}$ )	Pseudo Work Effort (p-h)
1989	25.79	40	0.645
1990	12.07	60	0.201
1991	17.57	50	0.351
1992	30.17	100	0.302
1993	4.81	5	0.962
1994	19.35	85	0.228
1995	42.69	150	0.285
1996	63.99	200	0.320
1997	42.86	200	0.214
1998	13.89	4500	0.003
1999			
2000	4.61	200	0.023
2001	6.26	200	0.031



# JET Annual Worker Dose

Maintenance Group Dose Vs. Pseudo Work Effort



# JET Annual Worker Dose

<b>Group</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>	<b>1999</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>Average</b>
AD	0.1%	0.3%	0.6%	0.7%	0.4%	1.1%	0.5%	1.8%	0.3%
EN	13.0%	16.7%	21.3%	36.9%	24.7%	44.8%	16.6%	20.0%	17.9%
FA	2.9%	2.9%	6.9%	13.5%	8.5%	14.2%	5.7%	30.0%	4.9%
MA	77.9%	73.0%	56.7%	23.7%	47.0%	18.6%	61.9%	24.4%	66.9%
OP	0.6%	1.5%	3.5%	9.1%	6.1%	9.2%	4.6%	12.0%	2.5%
SA	0.6%	0.8%	3.8%	3.3%	2.0%	2.3%	1.0%	1.1%	1.3%
SC	4.9%	4.8%	7.2%	12.9%	11.3%	9.9%	9.7%	10.7%	6.3%
<b>Totals</b>	<b>100.0%</b>								

## Preliminary Observations

- Vacuum leaks and water leaks account for a significant fraction of unplanned maintenance dose
- Unplanned maintenance dose accounts for a significant fraction of maintenance dose
- Maintenance dose accounts for a large fraction of total dose
- Tradesmen account for the largest fraction of the maintenance dose

## Preliminary Observations

- Collective dose is proportional to machine size (power)
- Individual dose is well below the ITER target (2 mSv/a)